



CLAIMS

Claim 1 (original): 1. Method for estimating the seismic illumination fold $|(\bar{x}, \bar{p})$ in the migrated 3D domain at least one image point \bar{x} , for at least one dip of vector \bar{p} , wherein the illumination fold $I(\bar{x}, \bar{p}; \bar{s}, \bar{r})$ for each (source \bar{s} , receiver \bar{r}) pair in the seismic survey is estimated, by applying the following steps:

– determination of the reflection travel time $t_r(\bar{x}, (\bar{p}); \bar{s}, \bar{r})$ from the source \bar{s} to the specular reflection point \bar{x}_r on the plane reflector passing through the image point \bar{x} and perpendicular to the dip vector \bar{p} and then returning to the reflector \bar{r} ;

starting from the diffraction travel time $t_d(\bar{x}; \bar{s}, \bar{r})$ from the source \bar{s} to the said image point \bar{x} and then returning to the reflector \bar{r} ;

– incrementing the said illumination fold $I(\bar{x}, \bar{p}; \bar{s}, \bar{r})$ related to the said (source \bar{s} , receiver \bar{r}) pair as a function of the difference between the diffraction travel time $t_d(\bar{x}; \bar{s}, \bar{r})$ and the reflection travel time $t_r(\bar{x}_r, (\bar{p}); \bar{s}, \bar{r})$.

Claim 2 (original): 2. Method according to claim 1, comprising the step of summatting each of the said illumination folds $I(\bar{x}, \bar{p}; \bar{s}, \bar{r})$ related to a (source \bar{s} , receiver \bar{r}) pair so as to determine the total illumination fold $I(\bar{x}, \bar{p}) = \sum_{\bar{s}, \bar{p}} I(\bar{x}, \bar{p}; \bar{s}, \bar{r})$.

Claim 3 (previously amended): 3. Method according to claim 1, wherein, during the incrementing step, the illumination fold $I(\bar{x}, \bar{p}; \bar{s}, \bar{r})$ is incremented using an increment function $i(t_d, t_r; \bar{s}, \bar{r})$ according to $I(\bar{x}, \bar{p}) = I(\bar{x}, \bar{p}) + i(t_d, t_r; \bar{s}, \bar{r})$, the said increment function taking account of the difference between the diffraction travel time $t_d(\bar{x}; \bar{s}, \bar{r})$ and the reflection travel time $t_r(\bar{x}_r, (\bar{p}); \bar{s}, \bar{r})$.

Claim 4 (original): 4. Method according to claim 3, wherein the increment function i is a function of the seismic wavelet $s(t)$.

Claim 5 (original): 5. Method according to claim 4, wherein the increment function i is expressed as a function of the derivative of the seismic wavelet $s(t)$ according to:

$$i(t_d, t_r; \bar{s}, \bar{r}) = s(t_d(\bar{x}; \bar{s}, \bar{r}) - t_r(\bar{x}_r(\bar{p}); \bar{s}, \bar{r})).$$

Claim 6 (original): 6. Method according to claim 4, wherein the increment function i is expressed as a function of the derivative $\bar{s}'(t)$ of the seismic wavelet $s(t)$ with respect to time according to:

$$i(t_d, t_r; \bar{s}, \bar{r}) = (t_d(\bar{x}; \bar{s}, \bar{r}) - t_r(\bar{x}_r(\bar{p}); \bar{s}, \bar{r})).$$

Claim 7 (original): 7. Method according to any one of claims 3 to 6, in which an a priori correction $w(\bar{x}, \bar{s}, \bar{r})$ of the illumination fold is taken into account by migration, comprising the step of incrementing the illumination fold $I(\bar{x}, \bar{p}; \bar{s}, \bar{r})$ related to a (source \bar{s} , receiver \bar{r}) pair by $i(t_d, t_r; \bar{s}, \bar{r}) \cdot w(\bar{x}; \bar{s}, \bar{r})$.

Claim 8 (previously presented): 8. Method according to claim 1, wherein the determination step includes the second order Taylor series development of the diffraction travel time $t_d(\bar{x}; \bar{s}, \bar{r})$ around the image point \bar{x} :

$$t_d(\bar{x}; \bar{s}, \bar{r}) = t_d(\bar{x}; \bar{s}, \bar{r}) + (\bar{\nabla}_x t_d(\bar{x}; \bar{s}, \bar{r}))^\top \cdot (\bar{x}_r - \bar{x}) + 1/2(\bar{x}_r - \bar{x})^\top \cdot \Delta_{x,x} t_d(\bar{x}; \bar{s}, \bar{r}) \cdot (\bar{x}_r - \bar{x}).$$

Claim 9 (original): 9. Method according to claim 8, wherein the specular reflection point $\bar{x}_r(\bar{p})$ is determined along the length of the said reflector such that the diffraction travel time at the said specular reflection point $\bar{x}_r(\bar{p})$ is stationary, according to the equation:

$$\bar{p}^\top \Lambda(\bar{\nabla}_x t_d(\bar{x}; \bar{s}, \bar{r}) + (\Delta_{x,x} t_d(\bar{x}; \bar{s}, \bar{r}) \cdot (\bar{x}_r(\bar{p}) - \bar{x}))) = \bar{0}.$$

Claim 10 (previously presented): 40. Method according to claim 8, wherein the specular reflection point \bar{x}_r and the reflection travel time $t_r(\bar{x}_r(\bar{p}); \bar{s}, \bar{r})$ are determined according to the following expressions:

$$\bar{x}_r(\bar{p}) = \bar{x} - M \cdot F^{-1} \cdot \bar{b}$$

$$t_r(\bar{x}_r(\bar{p}); \bar{s}, \bar{r}) = t_d(\bar{x}; \bar{s}, \bar{r}) - 1/2 \cdot \bar{b}^T \cdot F^{-1} \cdot \bar{b}$$

where:

- M is a (3×2) matrix described by two vectors extending along the length of the reflector, and therefore perpendicular to the dip vector \bar{p} ;
- \bar{b} is a (2×1) vector of first order derivatives of the diffraction travel time along the reflection plane: $\bar{b} = M^T \cdot (\bar{\nabla}_x t_d)$;
- F is a (2×2) matrix of second order derivatives of the diffraction travel time along the reflection plane: $F = M^T \cdot (\Delta_{x,x} t_d) \cdot M$.

Claim 11 (previously presented): 41. Method according to claim 10, wherein the determination step uses isochronic migration maps $t_d(\bar{x}; \bar{s}, \bar{r})$ specified for each (source \bar{s} , receiver \bar{r}) pair involved in the migration at each image point \bar{x} in the migrated 3D domain.

Claim 12 (original): 42. Method according to any one of the preceding claims, wherein the seismic illumination fold $I(\bar{x}, \bar{p})$ in the migrated 3D domain is estimated during the Kirchoff summation migration of seismic data recorded during the 3D seismic prospecting.

Claim 13 (previously presented): 43. Method for correction of seismic data amplitudes recorded during 3D seismic prospecting in order to compensate for the effect of non-uniform illumination of sub soil reflectors, comprising the steps of:

- estimating the illumination fold $I(\bar{x}, \bar{p})$ using the method according to claim 1,
- using the inverse $I^{-1}(\bar{x}, \bar{p})$ of the said ratio as a weighting factor to be applied to each of the said seismic data amplitudes.

Claim 14 (previously presented): 14. Method for selection of an acquisition geometry among a plurality of acquisition geometries as a function of the target of 3D seismic prospecting, comprising the steps of:

- determining the illumination fold $I(\bar{x}, \bar{p})$ by the method according to claim 1, for each of the acquisition geometries considered,
- selecting the acquisition geometry providing the optimum illumination fold as a function of the target.

Claim 15 (previously presented): 15. Method according to claim 2, wherein, during the incrementing step, the illumination fold $I(\bar{x}, \bar{p}; \bar{s}, \bar{r})$ is incremented using an increment function $i(t_d, t_r; \bar{s}, \bar{r})$ according to $I(\bar{x}, \bar{p}) = I(\bar{x}, \bar{p}) + i(t_d, t_r; \bar{s}, \bar{r})$, the said increment function taking account of the difference between the diffraction travel time $t_d(\bar{x}; \bar{s}, \bar{r})$ and the reflection travel time $t_r(\bar{x}, (\bar{p}); \bar{s}, \bar{r})$.

Claim 16 (previously presented): 16. Method according to claim 15, in which an a priori correction $w(\bar{x}, \bar{s}, \bar{r})$ of the illumination fold is taken into account by migration, comprising the step of incrementing the illumination fold $I(\bar{x}, \bar{p}; \bar{s}, \bar{r})$ related to a (source \bar{s} , receiver \bar{r}) pair by $i(t_d, t_r; \bar{s}, \bar{r}) \cdot w(\bar{x}; \bar{s}, \bar{r})$.

Claim 17 (previously presented): 17. Method according to claim 16, wherein the determination step includes the second order Taylor series development of the diffraction travel time $(x; s, r)$ around the image point x :

$$t_d(\bar{x}; \bar{s}, \bar{r}) = t_d(\bar{x}; \bar{s}, \bar{r}) + (\bar{\nabla}_x t_d(\bar{x}; \bar{s}, \bar{r}))^T \cdot (\bar{x}_r - \bar{x}) + 1/2 (\bar{x}_r - \bar{x})^T \cdot \Delta_{x,x} t_d(\bar{x}; \bar{s}, \bar{r}) \cdot (\bar{x}_r - \bar{x}).$$

Claim 18 (previously presented): 18. Method according to claim 17, wherein the specular reflection point $\bar{x}_r(\bar{p})$ is determined along the length of the said reflector such that the diffraction travel time at the said specular reflection point $\bar{x}_r(\bar{p})$ is stationary, according to the equation:

$$\bar{p}^T \Lambda(\bar{\nabla}_x t_d(\bar{x}; \bar{s}, \bar{r}) + (\Delta_{x,x} t_d(\bar{x}; \bar{s}, \bar{r}) \cdot (\bar{x}_r(\bar{p}) - \bar{x})) = \bar{0}.$$

Claim 19 (previously presented): 19. Method according to claim 18, wherein the specular reflection point \bar{x}_r and the reflection travel time $t_r(\bar{x}_r(\bar{p}); \bar{s}, \bar{r})$ are determined according to the following expressions:

$$\bar{x}_r(\bar{p}) = \bar{x} - M \cdot F^{-1} \cdot \bar{b}$$

$$t_r(\bar{x}_r(\bar{p}); \bar{s}, \bar{r}) = t_d(\bar{x}; \bar{s}, \bar{r}) - 1/2 \cdot \bar{b}^T \cdot F^{-1} \cdot \bar{b}$$

where:

- M is a (3×2) matrix described by two vectors extending along the length of the reflector, and therefore perpendicular to the dip vector \bar{p} ;
- \bar{b} is a (2×1) vector of first order derivatives of the diffraction travel time along the reflection plane: $\bar{b} = M^T \cdot (\bar{b} = M^T \cdot (\bar{\nabla}_x t_d))$;
- F is a (2×2) matrix of second order derivatives of the diffraction travel time along the reflection plane: $F = M^T \cdot (\Delta_{x,x} t_d) \cdot M$.

Claim 20 (previously presented): 20. Method according to claim 19, wherein the determination step uses isochronic migration maps $t_d(\bar{x}; \bar{s}, \bar{r})$ specified for each (source \bar{s} , receiver \bar{r}) pair involved in the migration at each image point \bar{x} in the migrated 3D domain.

Claim 21 (previously presented): 21. Method according to claim 20, wherein the seismic illumination fold $I(\bar{x}, \bar{p})$ in the migrated 3D domain is estimated during the Kirchoff summation migration of seismic data recorded during the 3D seismic prospecting.